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U.S. DEPARTMENT OF THE NAVY
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# Information Required From Planning Yards to Support Zone Logic

VIA-2

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## ABSTRACT

For over a decade, the use of zone logic, an operational approach consistent with modern manufacturing practices, has become more common in U.S. shipyards. Regarding naval ships, the most significant difference from traditional system-by-system orientation is the application of an implementation strategy even before basic design efforts begin for any combination of ship alterations (ShipAlts). This imposes a unique challenge to each of the approximately thirteen planning vards which are charged by the Naval Sea Systems Command (NavSea) with assessing the costs of, and when authorized developing designs for proposed ShipAlts. The challenge consists of grouping information during the various design stages in a way that makes planning yard design deliverables anticipate the needs of the implementing yards that will employ zone logic. Simultaneously, these deliverables must be suitable for use by eligible bidders who have not yet made the transformation to modern zone orientation. This paper provides guidance for planning yards. The need for them to act as production engineering surrogates until implementing yards are designated, is addressed. Typical planning yard outputs are also described.

## INTRODUCTION

The U.S. Navy's Fleet Modernization Program provides for the orderly planning of improvements to ships. Improvement ideas are systematically processed for further study. Dependent on the nature of a proposed improvement investment may be made to "...measure the degree of increase in the ship's capability to perform its mission and..." the estimated "...cost for materials, installation, and design resources needed to carry out the proposed improvement" [1].
Each approved idea becomes a Ship Alteration Proposal (ShipAlt Proposal or SAP), "... a baseline document which consolidates known technical and materials information...." which is entered into the Navy's Amalgamated Military and Technical Improvement Plan.

Next, each ShipAlt Proposal is usually assigned to a planning yard, specialized by ship class, for preparation of a Ship Alteration Record (ShipAlt Record or SAR) . In the process of preparing a ShipAlt Record, a planning yard ". ..updates and documents the complete technical requirements and specifications that define the alteration. This information forms the basis for ShipAlt installation design efforts and provides data on which ShipAlt programming decisions should be made." This activity is part of Estimating, one of the five major functions for any industrial management cycle (see Figure 1). Estimating is almost always performed by system. The process is the same as that employed by commercial-ship operators when they consult with their own technical staffs, or design subcontractors, during preliminary design activities for ship modernization.

Thereafter ShipAlt programming decisions involve many organizations, budget reviews, adjustments, and/or reassessment of requirements. Methods for implementing each ShipAlt are addressed. This represents the start of Planning. Hereafter, usage of just the word planning implies that design and material definition are included [2].

Ideally, the process leading to a list of approved ShipAlts would include customer/planning yard/implementing yard negotiations aimed at identifying the basic design information that should be used as contract design documents for a specific number of ShipAlts to be implemented simultaneously. The implementing yard's production engineers, as participants in the negotiations, would contribute the most cost-effective implementation strategy, consistent with achieving each ShipAlt's functional objectives, before the major expenditure of design man-hours.

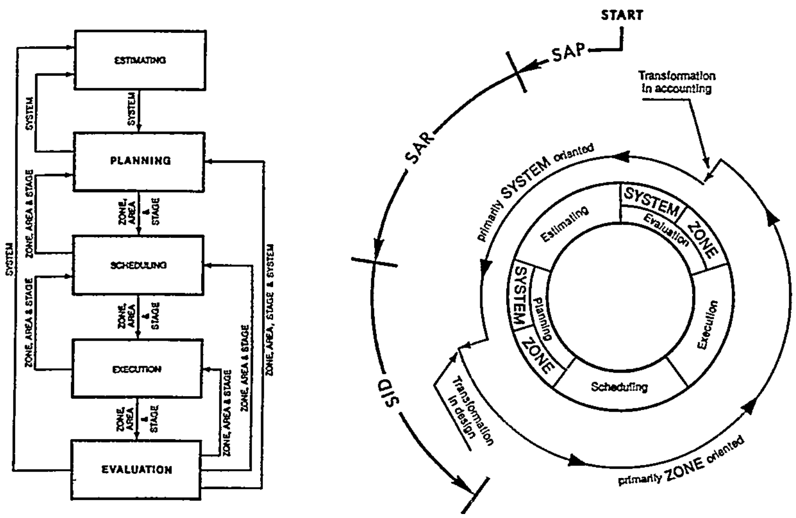



FIGURE 1: Two views of the management cycle for a zone oriented approach to any heavy industrial process, including ship construction, modernization, overhaul, and repair.

The arrangements shown on contract drawings, would then reflect productivity objectives, such as:

- combining foundations, even for different ShipAlt equipment,

- delineating separate outfit packages, regardless of different Shipalts represented, that will be assembled in shops and the sequence for their installation on board,

- maintaining distributive systems in parallel runs that are as straight as possible, regardless of systems represented,

- rip-out, redesign and reinstallation of otherwise unaffected nearby systems when such work would obviously reduce ShipAlt implementation costs, and

- providing sequenced zones per stages by type of work so that work of one type, heavy welding for instance, may be done at the same time for all systems within a zone.

In the absence of such guidance, planning yards insufficiently integrate ShipAlts and have little or no concern for probable overhaul work. Nor do they anticipate the sequence of production activities. They do not usually make transformations from system to zone orientation (see Figure 1), as needed for the more effective zonal approach that has been gaining acceptance in U.S. private shipyards since 1979 and in naval shipyards since 1982 [3,4].

In order to support productivity improvement through zone logic, planning yards should effect certain changes in the following drawing preparation and material definition areas:

- ShipAlt Installation Drawings (SIDs) - These include drawings for system diagrammatics, key arrangements, temporary access/egress, temporary shoring, rip-out, structure, arrangements, manufacturing, assembly and details, electrical diagrams, and cabling sheets as needed by an implementing yard. SIDs are comprehensive and exclude only the final drawings commensurate with final planning stages which are usually produced by implementing yards. SIDs may include integrated designs to "...represent work required by two or more ShipAlts, usually to be accomplished in the same space or area of the ship...." at the same time. "Completion of SIDs is to be accomplished no later than 12 months before start of scheduled availabilities (A-12)."

- Centrally Provided Material (CPM) - Items first defined in ShipAlt development documents, such as ShipAlt Records, and are designated for central procurement as Government-furnished material. Specific dispositions of CPM are included in Bills of Material (BOMS) that accompany SIDs.

- Locally Provided Material (LPM) - Items that are listed in BOMs that accompany SIDs and that are designated for material management (procurement and control) by implementing yards.

- Long Lead Time Material (LLTM) - This is another way of classifying materials as LLTM applies to both CPM and LPM.

The needed changes require that more production engineering be applied in planning yards before implementing yards are designated.

PALLET CONCEPT AND PALLET LIST

The word pallet has a unique meaning. To designers a specific pallet means the data (design details, material lists, work procedures, test instructions, etc.) needed to produce an envisioned interim product. To material management people the same pallet means the procurement and kitting of the specific materials required. And to production people it means the specific work effort that must be applied to produce that interim product. To production engineers, pallet has all of those meanings. As shown in Figure 2, a pallet serves as an information link which coordinates the efforts of people having different responsibilities, toward a common goal [5].

To palletize means to group information, material, and work as preparation for producing a series of discrete objectives (interim products). A pallet list is identification of the interim products required to complete a project. When a pallet list is presented in the sequence in which the work is expected to be performed, it is the most effective way to express a strategy for ship modernization that should be commonly followed by design, material management and production people. As shown in Figure 3, a production-engineered strategy for simultaneous implementation of any number of ShipAlts can and should be given to ShipAlt designers at least before they start that part of basic design that will become contract design, that is, a negotiated package which first of all does not affect ShipAlt functional requirements, but is consistent with the most productive methods known [6]. Pallet lists describe a production-engineered strategy for coordinating design, material and production management. There is no counterpart to the powerful pallet concept in traditional system-by-system operations.

A strategy for zone/stage orientation is ideal when it is: initially applied in a large-frame sense, subject to constant refinement as more design information becomes available, and dependent more on ship type and nature of work rather than on details of the work to be accomplished. As a consequence, the separation of planning yard designers from implementing yards, while it still remains a problem, diminishes in significance.

The zone/stage approach requires more and better quality planning in time to guide ShipAlt basic designers. Further, a zone/stage approach requires refinement of the implementation strategy as design progress makes more information available. As shown in Figure 4, starting with basic design, imposition of a strategy or refinement of a strategy always precedes design activity. Refinement continues until just before the final ShipAlt design stage when production engineering input becomes tactical in nature. Detail designers are then advised of the exact way that production needs information grouped on final detail drawings.

Unlike system-by-system design which is usually separate for each ShipAlt and also independent of other design activity, all stages of the design effort for zone/stage orientation are parts of a single process in response to a single strategy regardless of where design work is performed. Thus, information from planning yards to support zone/stage logic should conform to a strategy devised by a production engineering effort even if it is just for basic and functional design stages with the remaining design efforts performed by implementing yards.

DESIGN STAGES

As early as 1986, at least one planning yard which was also the implementing yard, through a special planning effort for modernizing a submarine, combined several "electronic" ShipAlts that required extensive rip out and reinstallation work. Because information was to be grouped by type of work within a zone rather than by system, designers were able to combine foundations for adjacent electronic equipment even though they were for different systems. This made it practical to finish machine foundations in shops and to organize the activities on-board in distinct stages by type of work, including shoring of platforms, ripping out, holding-coat painting, fitting requiring heavy welding, fitting requiring bolting or light welding, electric cable pulling and connecting, and final painting, for all ShipAlts simultaneously.

The overall process, within which design should inescapably be part of planning, may be described as starting with basic design. Basic design involves system-by-system organization of information together with arrangements that are overlaid with a generic, basic implementation strategy. In other words, the information being compiled would be organized as a matrix. When examined

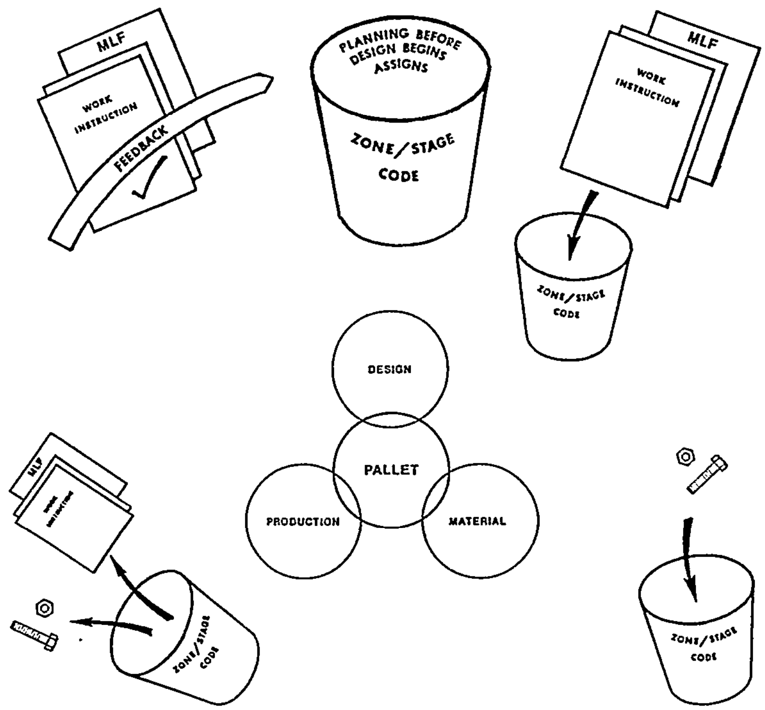



FIGURE 2: The pallet concept applied to ShipAlts. Pallet = zone/stage = interim product = work package.

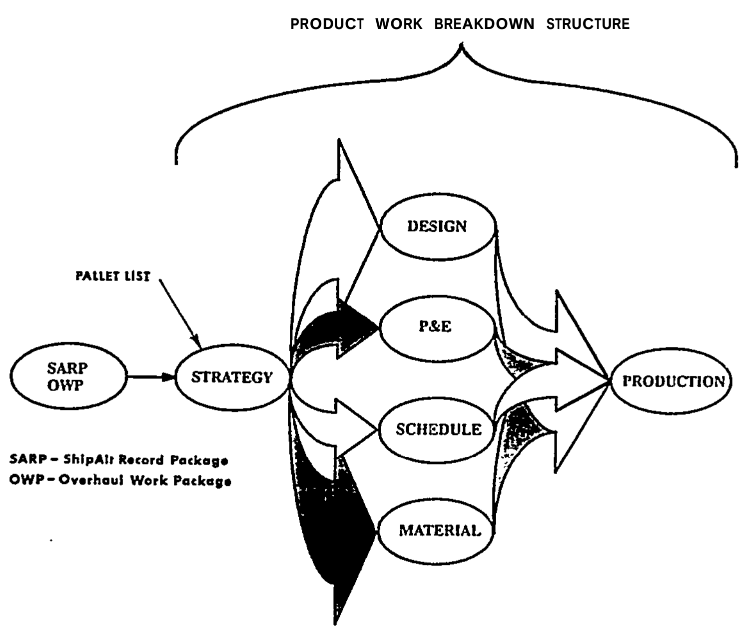



FIGURE 3: The zone approach characterized by strategic planning before design begins. The application of zone logic is greatly facilitated. (Provided by Philadelphia Naval Shipyard)

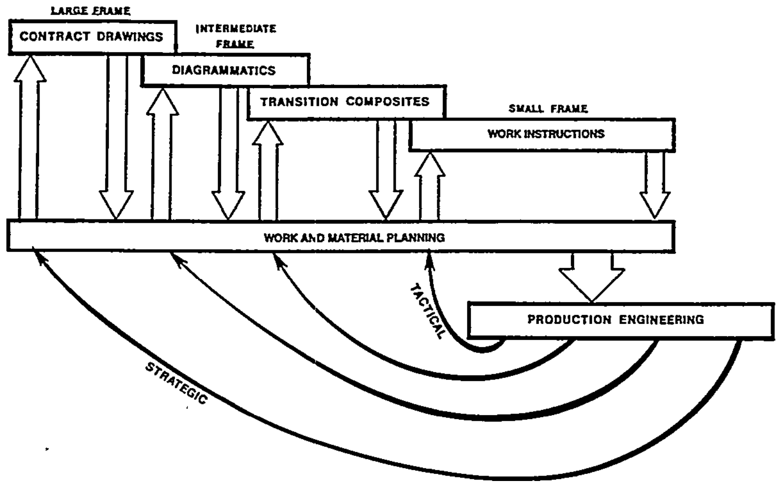



FIGURE 4: For effective ShipAlt implementation, production engineering inputs precede all design stages. Initially, the production engineering input is strategic and, as design progresses, it becomes tactical.

from one aspect, information would be grouped by system. When examined from a second aspect, information would be grouped by zone in a large-frame sense.

The second stage, functional design, should produce quasi-arranged diagrammatics and key drawings by system which fix functional aspects and which represent a degree of refinement of basic design. At the same time the zonal view of the information matrix would reflect a better, but not yet final, implementation strategy. This information grouping is said to be organized in an intermediate-frame sense. Both the first and second planning stages require ShipAlt designers to define all materials required. This means definition by either (a) exact identities and numbers required, (b) exact identities and estimated quantities, and/or (c) identification by material classes and estimated quantities, such as, "so many" lineal feet of medium-diameter electric cable.

Material definition should be refined to an intermediate degree during the second stage. The quasi-arranged diagrammatic should be subdivided by intermediate zones so that the location and receipt date requirements for certain materials may be estimated with enough assurance to initiate their procurement. This emphasis on material definition is extremely important. Many difficult to procure items, valve operators for example for which procurement in a system-by-system approach would be initiated relatively late, can and should be ordered from functional design information. The information is derived from a matrix that simultaneously identifies information grouped by systems and by zones in an intermediate-frame sense, that is in the context of a now refined generic, basic implementation strategy.

The third stage, transition design, requires the least number of man-hours, and should be implemented by experienced people having simultaneous understanding of ship operational, ship maintenance, and shipyard productivity matters. At this stage all information is "transitioned" to zone orientation. Transition designers establish the final routing of new and/or modified distributive systems per required ShipAlt arrangements and in the context of a finalized modernization strategy. Transition designers establish the rights-of-way for ShipAlt distributive systems, locate the positions of such things as valves and gages relative to machinery, delineate the space reservations required for maintenance, and show interface boundaries that zone-oriented detail designers are to observe. Whether or not subsequent efforts produce maintainable designs is very dependent upon the knowledge and expertise of those who perform transition design. Their outputs, plus the planning yard's file of standard details are all that are needed for effective control of detail design, that is, the final stage which produces information grouped in a small-frame sense. While the transition effects some degree of design refinement, it does not address material refinement.

As a consequence of design being regarded as an aspect of planning, the final or fourth stage, is also referred to as work instruction design. Instructions regarding safety, work procedures, disposition of ripped-out materials, etc., supplement design details and material lists. In some naval shipyards the final design products are referred to as unit work instructions. They are organized in 8 1/2"x11" booklets that are subdivided so that each segment provides all information required to perform work in a specific zone during a specific stage regardless of different systems [7].

Also, this final stage incorporates the detail requirements for producing pipe pieces and components other than pipe pieces. Thus, the entire planning process starting with basic design is one of constantly subdividing and sorting information [8].

## THE PRODUCTION ENGINEERING FUNCTION

Production engineering is most effectively applied as a decentralized pervasive function which has two objectives for each undertaking:

- completion of a project to the customer's satisfaction, and

- manifest improvement in the implementing yard's manufacturing system during execution of the project.

If one of the objectives is achieved without the other a shipyard manager has failed. Both directly impact on the Navy's mobilization potential. Because implementing yards do not have enough understanding of the imperative need for both objectives, they have not, as of 1990, made sufficient pertinent demands on planning yards. Nor have Navy project and program managers, because their missions do not include constant development of manufacturing systems.

Imposition of a production-engineered strategy even as basic design starts and constant refinement of the strategy as subsequent design stages make more information available, is a shipyard manager's way of saying, "I have to protect the methods which enable me to constantly improve the manufacturing system." Thus in a climate of extreme competition, a close association between production engineers and designers, wherever they are located, is essential for a shipyard's survival and for the Navy's ability to get the greatest return from available funds.

Ideally, a production engineering effort requires a few dedicated high-level production engineers from an implementing yard at time of basic design, a larger number of field engineers who are regularly assigned to shops at time of functional design, the same high-level production engineers at time of transition design, and the actual foremen who will supervise the work at time of detail design (see Figure 4). Regardless of their positions, all would understand that their participation in decentralized production engineering is a regular work responsibility.

While sharing their predecessors' concerns for safety and productivity improvement, foremen, in their production engineering roles, would be primarily concerned with inputting things of a tactical nature, such as, dividing a pallet into smaller work packages and specifying rip-out sequences. Thus, required lead times and work volumes would be greatest for high-level production engineering, would reduce commensurately through the intermediate level, and would be least when foremen provide their inputs (about four to six weeks ahead of scheduled starts for work volumes in the order of forty to 120 man-hours).

In each design stage for a vessel modernization effort, the totality of the project is always discussed but in a different level of detail. For example, during basic design there are relatively few information groups visible from the zone side of the information matrix, each are relatively large, and the information contained is relatively vague. Subsequent design stages increase the number of groups, decrease their sizes, and provide more exacting descriptions of modernization requirements. Information becomes available at an exponential rate. As a consequence, more and more people are required to participate in the production engineering function in order to constantly analyze a developing design and to constantly refine (not change) the strategy.

But in most instances implementing yards are not yet designated when ShipAlt basic design starts. Rather than proceed in a production engineering vacuum, design work should proceed in the context of a basic ship modification strategy that is peculiar to a ship class until an implementing yard is designated. Further, a few qualified production engineers should be employed in each planning yard to act as if they were in a zone-oriented implementing yard until an implementing yard is designated.

Basic ShipAlt designers account for the least expenditure of man-hours, but have the greatest impact on total ship modernization cost. Other designers and material management people account for a greater amount of man-hours and have the next greatest impact. Production people, while accounting for the greatest expenditure of man-hours by a wide margin, have very little impact on total ship modernization cost (see Figure 5). Thus, the key to productivity improvement is in more and better quality ShipAlt planning which will direct design and material management to

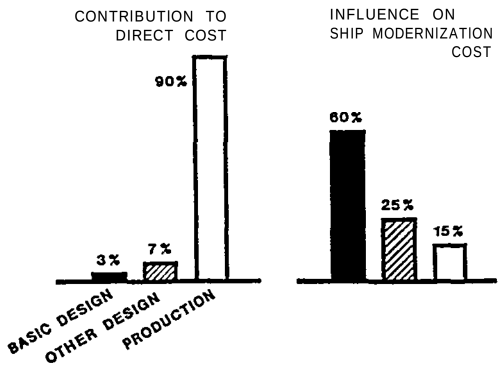



**FIGURE 5:** A typical comparison of direct cost to its influence on ship modernization cost.

exactly anticipate how production will be implemented. Regardless of the split design responsibilities, it would seem that the manufacturing process for a ShipAlt commences with the start of contract design, that is, all design, material marshalling, and production activities would be in accordance with a single strategy (see Figure 6).

Strategies to the extent that they are described herein, are only intended as models. It is strongly recommended that sufficient funding and high priority should be applied for retaining production engineers who have extensive experience in applying zone logic for shipyard applications. They should work with teams of planning yard designers and prospective production engineers to further develop basic strategies for classes of carriers, submarines, surface combat ships, and auxiliaries [9].

## BASIC STRATEGY/SPECIALTIES

The number and nature of required specialties are dependent on ship type and are applied for design just as they are for production. An auxiliary ship may require specialties only for machinery, accommodations, electrical/electronics, and a category sometimes called deck that includes everything else (see Figure 7).

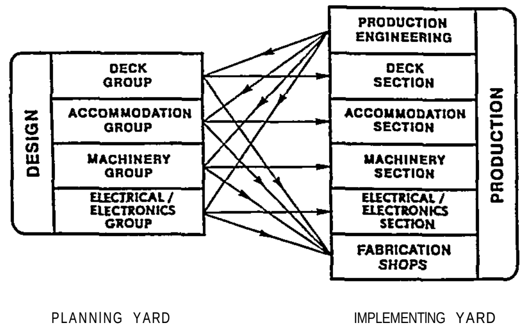
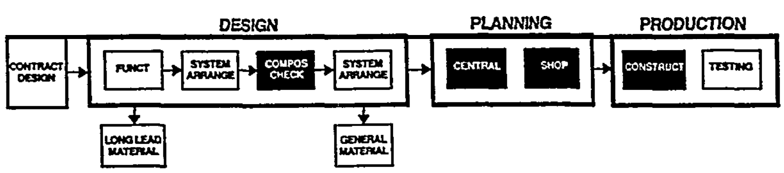



**FIGURE 7:** Expertise in designing and manufacturing parts and assemblies per problem area is substituted for traditional functional expertise.

### Traditional System Orientation




### Modern Zone Orientation

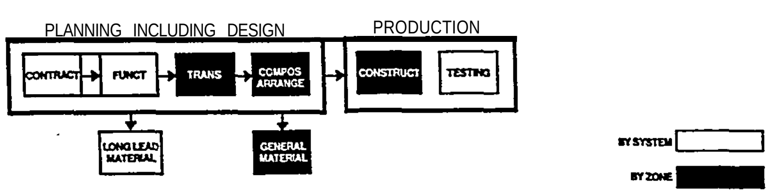



**FIGURE 6:** Traditional vs. modern manufacturing systems. The former features planning after design. The latter features more and better quality planning before each design stage.

For overhaul and modernization of an aircraft carrier, ten specialties may be employed.

0 Services, dock work and miscellaneous.

1 All tank work (cleaning, painting, piping, structural, testing), tanks tops, and hull structure.

2 All work in main machinery spaces and associated shaft alleys (except tank-top repairs).

3 Auxiliary machinery spaces and all associated work (except tank-top repairs).

4 All magazine work (except tank-top repairs).

5 All pump room work, emergency-generation spaces, air-conditioning spaces, and rudder work.

6 Spaces from third deck to main deck (primarily, but not limited to, accommodation spaces).

7 Hangar bay.

8 Spaces from main deck to flight deck (primarily electrical/electronic spaces) plus island.

9 Flight deck.

How they are imposed is illustrated in Figure 8 [9].

The specialties shown only denote basic separation by problem categories, an aspect of Group Technology (GT). Figure 8 also shows that a multiplicity of regions having the same problem category (Specialty 5) are not contiguous to each other nor do they conform with main structural divisions. This is because they represent separation by problem category only.

Geographical representation of a specialty simply designates a sphere of responsibility assigned to a design team and its companion team in production, that have interim product expertise peculiar to a specialty. In some yards the word zone is used in place of specialty. Problem zone or any other term that implies separation by problem category is preferred. The reason for this distinction is to avoid confusion with pallet or zone/stage.

Zone denotes a geographical division and stage refers to a separation in time. Control of work mav be achieved bY either one, but the most flexible and most effective way to control work is by their usage in combination, zone/stage. If a particular zone is opportune at one point in time, it does not have to be retained if it is not opportune at a different time. For example, structural work on a bulkhead requires a zone that encompasses the bulkhead with sufficient space reserved on each side to facilitate structural work. Later on a zone that is made up of one or more compartments makes better sense for painting work. Such usage of zone/stage for electric cable pulling through all specialty regions is a better and more complex example [10].

Obviously zone/stage work packages often have to straddle the boundaries between specialties. In each such case, the different specialists have to coordinate their planning with each other. Packaging work by zone/stage per specialty is means to assure that different work teams are not unintentionally in the same zone at the same time. There is no counterpart planning technique in system-by-system operations. Therein, workers have to compete for access to on-board work, because the planning performed for them is incomplete.

Also, zone-oriented production engineers are able to advise designers of a manufacturing system's most effective work flows. From the beginning and through continuous interaction with designers, their objectives include getting as many zone/stage work packages into preferred problem areas. That is, as much as possible work is performed in rationalized work flows. Job shop work is minimized.

As prerequisites for effective implementation of zone logic, the specialty regions and planned zone/stage/problem area classifications of work have to be considered even for the earliest required ShipAlt Installation Drawings (SIDs) and their attendant bills of material (BOMS).

LARGE-FRAME PLANNING

Each specialty in design and its production engineering counterpart, basically proceeds as if the region for which it is responsible is a separate ship. Of course there must be coordination with other specialists at numerous interfaces, some of which can be very significant.

With only the earliest available information, such as Ship Alteration Proposals (ShipAlt Proposals or SAPs),

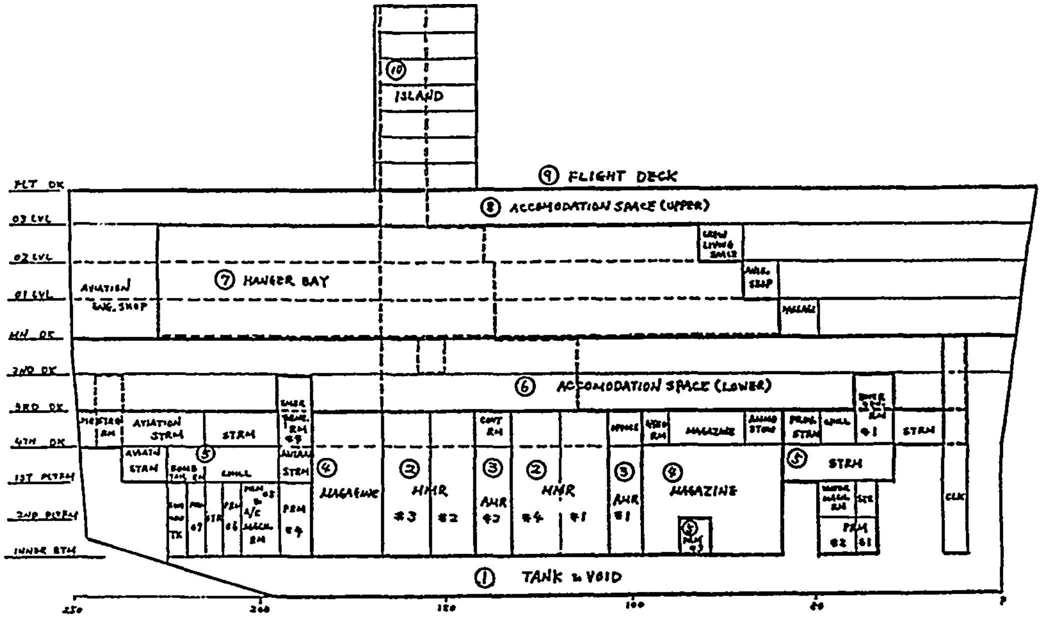



FIGURE 8: Specialties employed for modernization of an aircraft carrier. (Provided by Philadelphia Naval Shipyard)

**TABLE I:** Generic pallet list for an electronic space

| | | |
|---|---|---|
| Complete Space | 1 | Tagging equipment and fittings with disposition instructions. |
| Complete Space | 2 | Disconnecting electric cables. |
| Lower only | 3 | Removing equipment and fittings that do not require extensive gas cutting. |
| Lower only | 4 | Removing electric cable. |
| Lower only | 5 | Removing fittings, including foundations, that require extensive gas cutting. |
| Complete Space | 6 | Removing insulation. |
| Upper Only | 7 | Removing electric cables. |
| Upper Only | 8 | Removing fittings that do not require extensive gas cutting. |
| Upper Only | 9 | *Removing* fittings, including foundations, that require extensive gas cutting. |
| Complete Space | 10 | Clean and prime. |
| Upper Only | 11 | Fitting by heavy welding. |
| Lower Only | 12 | Fitting by heavy welding. |
| Complete Space | 13 | Touch-up followed by 1st-coat painting. |
| Upper only | 14 | Fitting by light welding and bolting. |
| Lower Only | 15 | Fitting by light welding and bolting. |
| Complete Space | 16 | Touch-up followed by remaining painting. |
| Complete Space | 17 | Equipment tests. |

and knowledge of a ship class, production engineers/specialty are able to negotiate with customers and designers in order to create a mutually acceptable pallet list (strategy). This is not particularly difficult for specialists because they only have to express a strategy in terms of zone/stage/problem area designations. Specialty Number 1 for tanks and voids, as shown in Figure 8, provides the simplest example. Zone/stage/area work packages could be sequenced by the specialists to start aft and go forward as a single work flow or, production manpower permitting, as two flows progressing side by side. Also, each zone could address a single tank or a group of adjacent tanks dependent upon the degree of control desired.

For tank cleaning, scaffolding and temporary service installations, holding-coat painting, inspection, and the rip out of fittings, it makes sense for zones to coincide with boundaries formed by structure. For rip out and replacement of structure, zones that encompass the structural boundaries are required. Thereafter, zones that are made up of single tanks or groups of tanks should again be employed for installing fittings and for painting. The clever composition of a zone/stage list insures, for example, that a team dismantling fittings on one side of a bulkhead is not endangered or disrupted by people assigned to make cuts through the bulkhead from its other side.

The sequence for work is organized like a series of rolling waves, wherein the crest of each represents a category of work (problem area). Thus the team assigned to tank cleaning leads, followed in succession by other teams with zone/stage control assuring that no two teams are unintentionally in the same zone during the same stage.

Another example which pertains to extensive modernization of an electronic space could employ two zones that are separated by a horizontal parting plane at about midway between the deck and the overhead, that is, upper and lower zones. A generic pallet list for such spaces is illustrated in Table I. This pallet list should be thought of as a series of empty buckets of varying sizes, that have yet to be filled with the detail design information, materials, and skills needed for realizing a series of different interim products (see Figure 2).

The earliest produced SIDs, such as General and Machinery Arrangements, should incorporate identification of the specialties that will be involved, the extent of their involvement, the boundary areas that require special coordination by two or more specialties, and the basic, often generic, pallet definitions. In addition to the locations for major equipment, lists of all material required should also be grouped to match the specialties, but only as (a) exact identities and required numbers, (b) exact identities and estimated quantities, and/or (c) identification only by material classes and estimated quantities. This material compilation, broken down by specialties and the corporate history of man-hour/material relationships comprise a solid framework for the largest frame budgets and schedules. Planning that is consistent with zone logic vastly improves the quality of information in ShipAlt Record packages before they are sent to cognizant approval authorities.

The process for ordering major items that are classed as both Centrally Provided Material (CPM) and Long Lead Time Material (LLTM), with information thus far available, is not different from that traditionally employed.

The first of the SIDs produced, such as general arrangements, in addition to reflecting commitment to meet customer requirements, contain the strategy framework achieved by production engineer/designer interaction. The framework is susceptible to refinement but not to change per se. Thus, the SIDs which are the equivalent of contract drawings in the commercial world, should document production's commitment to a strategy before the major expenditure of design man-hours.

Actually, the zone logic planning thus far regarded as large-frame planning, leapfrogs ahead into small-frame planning when the specialists provide previews, their pallet lists. These however, are the empty buckets, identified by title and code, which are still unrefined and which have yet to be filled with the detail design information, materials, and skills needed for realizing a series of different interim products.

## INTERMEDIATE-FRAME PLANNING

Intermediate-frame planning, in addition to functional design, is chiefly concerned with production and material control matters. It provides good enough estimates of certain materials, other than CPM or LLTM, for which special control and release of purchase orders before detail design starts, are extremely beneficial.

Approval authorities would further benefit because functional drawings are required to be more sophisticated than those traditionally prepared. All aspects that affect safety and operations are included (in the commercial world that includes virtually everything for U.S. Coast Guard and American Bureau of Shipping approvals). The objective is to minimize, if not eliminate, the need to submit drawings for approval after relatively intensive detail design efforts begin. Further, designers are required to quasi-arrange diagrammatics.

Each Material List per System (MLS) still addresses all materials required for a system. But because more information is generated during functional design, a MLS reflects considerable refinement. The identities and quantities of more material items are exactly known. Thus, a MLS, while not yet exact, contains fewer identifications by just material classes and fewer estimates of quantities required.

The most advanced application of zone logic features a computer program to compare materials as they are being defined in the intermediate-frame planning stage to those which were identified during the earlier large-frame planning stage. The program sorts and collates in order to answer two questions:

1) Are any materials now being defined for the first time? and

2) If not, do quantities now being defined exceed those in the material budget developed as part of contract design?

Newly identified and/or revised quantities of materials are immediately addressed by material managers for their procurement significance. But more important, because of the material/man-hour relationships derived from corporate history, approval authorities and others concerned with production control, before an implementing yard is designated, are simultaneously being warned by the computer that man-hour budgets should be adjusted and schedules should be confirmed or changed accordingly. The terms material volume and work volume are synonymous.

Another profound improvement in the content of ShipAlt Records results from production engineers per specialty having to divide the regions for which they are responsible into a reasonable number of intermediate zones (in warships perhaps as few as five and as many as fifteen for each specialty). Further, production engineers are required to sequence the intermediate zones consistent with how they plan the progression of work.

The boundaries of intermediate zones and their sequencing do not have to exactly encompass a group of zones/stages defined in previously conceived pallet lists, because intermediate zones/stages are only used to get better estimates of material and work volumes as needed for:

- man-hour budgeting and scheduling in an intermediate-frame sense, and

- issuing purchase orders for certain materials, which specify just-in-time deliveries in relatively small lots, immediately upon designation of an implementing yard, that is, without having to wait for material lists which accompany later prepared detail design drawings.

As means to achieve these objectives, functional designers should overlay their quasi-arranged diagrammatics on the defined intermediate zones. The overlays then show what portions of various systems are likely to appear in each intermediate zone. Functional designers should also make corresponding divisions in each MLS.

The latter action sets the stage for release of initial purchase orders that specify just-in-time deliveries for certain materials, before detail design starts. Thus, the name Material Ordering Zone (MOZ) is used in place of Intermediate Zone. Material procurement gets a tremendous jump start.

Intermediate-frame planning, of course, encompasses the preparation of functional drawings. At the same time, with no less priority, it too leapfrogs ahead with its strong emphasis on accelerating definition of materials, and when necessary even initiating their procurement. The material information is grouped for just-in-time deliveries in an intermediate-frame sense, and simultaneously, in a way that facilitates later subdivision by detail designers for just-in-time deliveries in a small-frame sense.

## TRANSITION PLANNING

Transition planning is unique to zone logic. Some regard it as the beginning of detail design efforts, but its importance justifies treatment as a distinctly separate function. Transition planning is the last opportunity to nail down significant operational, maintainability, and productivity features. Further, the completion of transition planning is a natural juncture for the transfer of planning responsibilities from a planning yard to an implementing yard,

Again, specialists match problem categories. Fortunately the transition stage requires the least expenditure of man-hours, but because of the breadth of knowledge required, the best available people should be employed. In the context of specialties, transition planners have to understand ship operational and maintenance matters and prospective implementing yards' manufacturing systems.

Transition experts use as their primary inputs, contract arrangement drawings, diagrammatics, and pallet lists. They:

- overlay distributive system diagrammatics on contract arrangements in order to show system paths and their relationships to each other,
- designate foundations that should be combined and/or integrated with hull structure, regardless of systems,
- designate the approximate positions of controls, valves, gages, light fixtures, ventilation outlets, etc., not already fixed on contract drawings, relative to important equipment and machinery so as to enhance their operation,
- designate space reservations for maintenance and routes for initial installation of machinery and equipment as well as for their removal and reinstallation during future overhauls,
- designate requirements for extraordinary shoring, scaffolding, and temporary services,
- refine and superimpose the pallet list (zones/areas/stages) geographically and by coding on the planning yard's design model, and
- designate contingent pallets for CFM and LLTM that could cause significant disruption if delivery dates are missed.

In other words, transition planners per specialty create mechanisms for immediate control of detail design in order to insure operability, maintainability, and productivity, without themselves being involved in detail design. As planning yard transition documents should be incorporated in ShipAlt Records together with standard design details, they-are powerful means for approval authorities to control detail design development by implementing yards and/or subcontractors.

The refined pallet lists, as superimposed on a design model, are for use by implementing yards to assign detail design responsibilities by zone/stage, regardless of svstems represented, and to identify interfaces between pallets.

Transition planners should have little need to request approval to deviate from general and machinery arrangements, because they would probably be the same individuals who provided production engineering input during the large-frame planning stage. Their thinking, introduced during customer/planning yard negotiations a short time before, should already be in the arrangements mandated by ShipAlt Records. The changes, really adjustments, they might propose during transition planning would for the most part be of limited scope and as consequences of functional drawing and MLS developments.

With Computer Aided Design (CAD) there is some risk that designers will continue to use the developing design model without pausing to record the end of the transition stage. That is, they could further manipulate what is in the computer for further design development without making a record of what transition planners imposed. Having access to the transition planning afterwards is obviously important for discussions that could come up during and following detail design. Having files of transition planning from past modernization efforts, is also important because they could be applied to future projects by adaptation and because they are needed for teaching transition planning.

## SMALL-FRAME PLANNING

Planning yard people should understand the final planning stage that normally would be assigned to an implementing yard. The entire effort, from the start of large-frame planning to the delivery of a modernized ship, has to be regarded as part of a single manufacturing system in which design is a true aspect of planning. Production engineers and designers at all levels, in both planning yards and implementing yards, should be the recipients of feedback from completed work packages. All are obligated to analyze-results. Analysis is greatly facilitated when cost/schedule returns are per types of interim products, that is, per rationalized work flows.

Proposed changes in work methods or design details that may benefit a particular stage in a particular work flow, also have to be evaluated for their impact on the entire manufacturing system. Each planning yard functionary, therefore, should understand the entire process at least within the context of an assigned specialty.

Also, the transfer of responsibilities from a planning yard to an implementing yard at the end of a transition stage is not always practical nor, in some instances. desirable. For example, if the proper operation of a complex weapons control space is very dependent on the exact locations of all equipment and fittings, the planning yard may have to perform detail design as a customer imposed condition even before an implementing yard is designated.

Transfers of planning responsibilities do not have to be made at the same time for each specialty, nor even for different groups of ShipAlts within a specialty. What should be transferred and when it is transferred should be the consequence of customer/planning yard/implementing yard negotiations. Additional factors to be considered include time remaining before a ship availability starts, unique expertise, and the planning (including design) workloads in both the planning yard and in the designated implementing yard. Regardless of how the remaining planning activity is assigned, that which is transferred and when it is transferred should be the consequence of a formal transfer meeting and a written transfer agreement.

Thus, for ideal grouping of information to support zone logic, planning yard people have to understand the application of a PWBS for a manufacturing process, starting with review of the Ship Alteration and Repair List (SARP), or such other authorizing document, through test and operation (sea trials). A typical PWBS, modeled to include rip-out and installation of fittings, is shown in Figure 9. Planning yard people would have to also understand how the same logic is employed for structural and painting work in order to plan for integrated structural, fitting, and painting work [5,11].

Planning yard production engineers, until relieved by implementing yard production engineers, should lead designers in a process that may be characterized as continually assessing, refining, and regrouping available information. The process should progress, as a baton passed in a relay race, when implementing yard production engineers and designers take over until the information is sufficient and its grouping is ideal, for rationalized work flows.

A tremendous advantage that stems from specialization, is that the degree of detailed information and the way it is grouped does not have to be the same for each specialty. A zone technology work package for complex electrical and electronics work to be accomplished in a specific zone during a specific stage, or even in a series of stages, may consist of an 8 l/2" by 11" booklet made up of a cover sheet and a number of distinct sections as shown in Figure 10. In contrast, a work package for piping renewals for all systems in a group of contiguous tanks, can consist of one composite drawing that is overlaid and coded for zone/stage/area control. The composite would also feature a material list that is divided to match the planned implementation of work [7].

Regardless of whether booklets or composites alone are used, all systems, including tubing, should be included. Exceptions should be limited to short runs of lighting circuit cable and short lengths of tubing in the vicinities of gages. Allowing systems to be field run is the same as giving away control.

Initially, booklets like that described in Figure 10 are sometimes justified only until workers who, in the past were required to apply only their craft expertise, have developed expertise per product. How to simplify work instructions without losing control should be continuously analyzed following implementation of work.

Even ShipAlt work in a space that is moderately complex and requiring CPM and/or LLTM, could be controlled by a single composite drawing having overlaid zones accompanied by codes that identify stages and problem areas. The material list could be conventionally prepared but would have to be supplemented by two columns. One would identify the pallet destination(s) for each line of material (instructions for material marshalling people). The second would identify contingent pallets for CPM and/or LLTM. This latter requirement is very important.

In effect, contingent pallets are warnings to the customer, planning yard, and implementing yard people concerned with events leading to material palletizing. Because productivity indicators are different for something that could have been fitted in a shop assembled unit or landed in a relatively accessible space on board, as compared to later landing the same item in what has become a relatively inaccessible space on board, the required increase in the man-hour budget and the shift in the man-hour distribution due to late delivery is known beforehand. In other words the impact on productivity and schedules are preassessed, mostly analytically determined in the absence of emotional argument, and very clear.

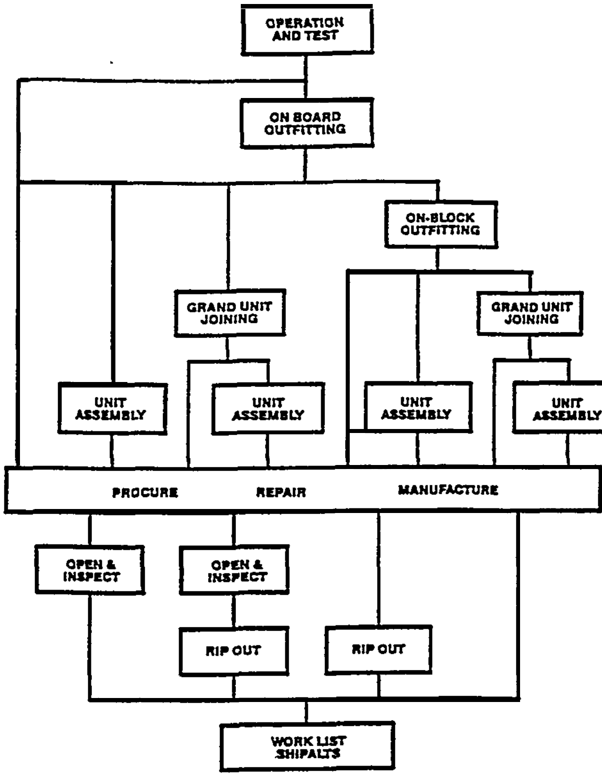



FIGURE 9a: Typical work flows by problem area for ship modernization.

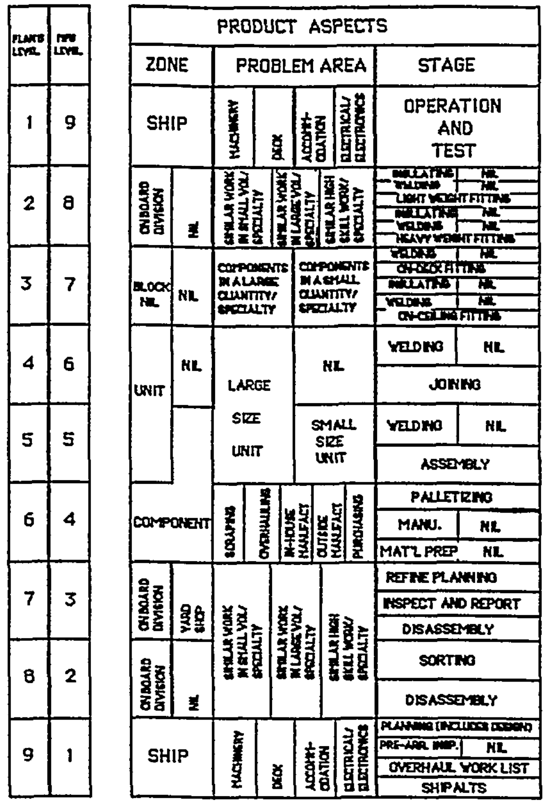



FIGURE 9b: Typical manufacturing levels and product aspects for ship modernization.

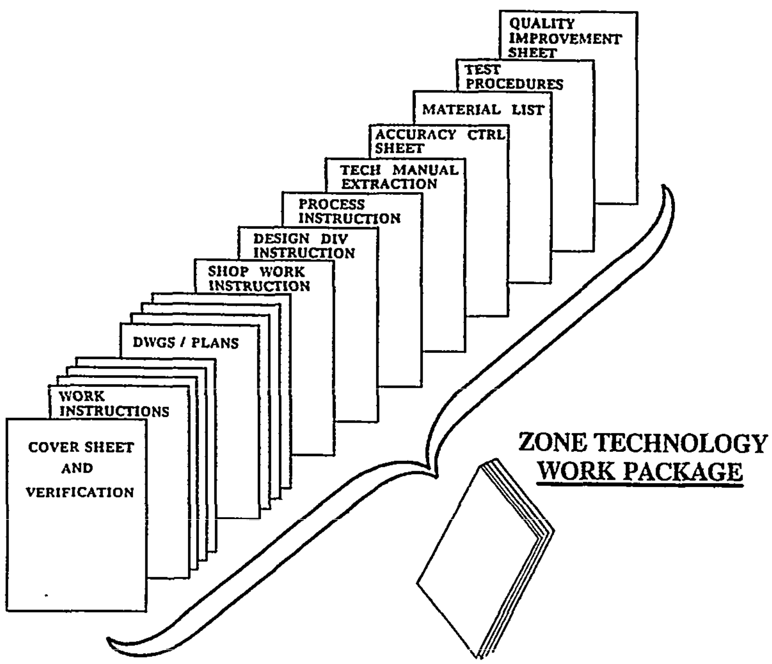



FIGURE 10: A work instruction booklet could incorporate a number of pallets. (Provided by Philadelphia Naval Shipyard)

Some people who are responsible for timely delivery of CFM are not likely to be enthused about the contingent pallet concept "because it gives claims advantage to implementing yards." They should be made to understand that all material procurement matters, no matter how remote or when initiated, become a de facto part of an implementing yard's manufacturing system. The use of rationalized work flows also facilitates effective analysis of problems and the extent of their impacts. Regardless of who is responsible, the Navy's best interest is always served when the impacts of late materials are accurately identified and assessed. Otherwise, attempts to improve material support activities will be futile.

Detail designers also have to be given production engineering guidance about what different fittings impose the same type of work so that they may be incorporated on the zone/stage composite regardless of systems represented. An example of work that should be included on the same composite is shown below. Each dash or heading if there are no dashes would represent an individual composite. Similar lists should be prepared separately for each specialty.

Tagging
- All electrical/electronic equipment, furniture, pipe, ventilation duct, lightweight foundations to be removed.
- All heavy foundations, stanchions, beneath deck stiffeners to be removed.
- All electric cable to be removed.

Removing Small Fittings
- Generally everything limited by weight and length that one worker can remove safely (includes electrical/electronic equipment, furniture, pipe, ventilation duct, and lightweight foundations).
- Electric cable.

Installing Shoring & Scaffolding

Removing Large Fittings
- Generally everything for which more than one worker is required for safe removal (includes electrical/electronic equipment, furniture, large diameter pipe, ventilation duct of extraordinary length, heavy foundations and beneath deck stiffeners).

Cleaning & Holding-Coat (primer) Painting

Laying Out Reference Lines and Points (for all systems)

Fitting Large Components
- Generally everything for which more than one worker is required for safe installation (includes electrical/electronic equipment, large diameter pipe, ventilation duct of extraordinary length, heavy weight foundations and beneath deck stiffeners).

Inspecting (for compliance with dimensional tolerances and weld quality).

Removing Shoring & Scaffolding

Installing Small Fittings (small diameter pipe, ventilation ducts, electric cable lengths, etc.)

Connecting Electric Cable Ends

Testing (initial phase)

Painting (all but finish coat)

Testing (final phase)

Cleaning, Painting (final coat) & Labeling

How the fittings are grouped should be based upon the equivalence of work. They should not be grouped to reflect how production shops are organized unless the shops themselves are product oriented. Often, the separations are influenced by work volume, access to work, skills available, and materials available. The grouping of information to facilitate productivity should be used as the basis for developing product trades, individuals or teams having all skills necessary to produce a class of interim products regardless of the systems represented. In other words, people should be grouped to match a PWBS [9,12].

The process of data reduction which started during large-frame planning and which is thus far described through pallet definition, is still not complete. In traditional organizations what remains, the detail planning for pipe pieces and components other than pipe pieces, is regarded as part of production. Detailing for the manufacture of pipe pieces in pipe shops and mold loft operations for structural work, are examples. Regardless of where performed, what should be understood in planning yards as well as in implementing yards is that such activities are a continuation of the planning process shown in Figure 4.

Zone logic, which uniquely provides for systematic data reduction from large-frame to small-frame focus, also identifies arbitrary restraints that prevent the full exploitation of cAD facilities. For example, the planning process can easily continue in a planning yard until it produces the data, such as, sketches, tables, printouts, material lists, and even NC code required for manufacturing components such as pipe pieces, ventilation duct sections, precut electric cable lengths. distributive system supports, foundations, ladders, and walkway sections.

If CAD systems are generally available and compatible, the planning yard produced design model can be readily transferred to an implementing yard after any planning stage. Similarly, because CAD terminals can be made available in shops, a yard planning department can readily defer the detailing of components, or even the preparation of some zone/stage work packages, to yard shops. With the same ease, a yard planning department can assign such work to qualified subcontractors.

Since only completed components, including those to be overhauled or modified, appear as line items in MLFs and the materials from which they are assembled appear in MLPs and MLCs, the MLF/MLP and MLF/MLC relationships are those of structured material lists. MLP and MLC represent the last division of information in the planning process.

As envisioned by planning yard production engineers at the very start! work associated with each MLP and MLC is a pallet which also has zone/stage/area classifications. But, as long as pallet completion dates are met, a shop manager working only with problem area classifications, can fully exploit GT for internal shop operations independent of how GT is exploited elsewhere. This permits just-in-time batch fabrication or overhaul of different components, of varying designs required in different quantities, on rationalized work flows.

## THE BENEFITS OF COMBINING SHIPALTS: A SPREAD SHEET APPLICATION

The identification of potential ShipAlts to be accomplished for a given availability is an iterative process. Often there can be considerable change in both the number and type of ShipAlts that are addressed from the earliest planning stages until the final work scope is chosen. Additionally, this uncertainty makes the development of meaningful cost estimates for various combinations of ShipAlts difficult to obtain. Consequently, a simple tool to monitor and help evaluate numerous combinations would be useful, both for Planning Yards throughout the planning process and for Navy decision-makers, as they consider cost and operability tradeoffs.

The development of a generic overhaul strategy for ship types has been described previously. In effect, this strategy provides a list of zone/stage pallets by specialty. In the context of this available generic strategy, ShipAlt designers can identify pallets impacted by potential ShipAlts very early in the planning process. In fact, one of the first tasks of the planning yard should be to identify these pallets associated with each ShipAlt. Once this has been accomplished, the information can be input to a spreadsheet matrix, which has the pallet list that forms the generic strategy on one axis, and the ShipAlts under consideration on the other axis, as shown in Table II. The four specialties employed in this example are the likely ones for a naval auxiliary, including machinery (M), deck (D), accommodations (A) and electrical/electronics (E/E). The row headings show there are three different ShipAlts under consideration. Thus, as multiple ShipAlts are considered and entered into the spreadsheet, a record of the pallets required is developed, and the potential synergistic benefit of performing combinations of two or more ShipAlts is identified and computed.

After each ShipAlt has been analyzed only in enough detail to identify pallets required, data can be entered into the spreadsheet. A "1" input into the cell for a specific pallet and a specific ShipAlt indicates that a pallet is required to complete the ShipAlt. Cells for pallets not impacted by the ShipAlt have "0" entered. As additional ShipAlts are identified and the estimating process begun, data are input to the spreadsheet for additional columns reflecting the pallets impacted by these additional ShipAlts. Table III shows the spread sheet with initial data (for three fictional ShipAlts) input. Note that the initial planning and design analysis is only to identify pallets by specialty involved in each ShipAlt. At any point in this process, the spreadsheet matrix can be screened to identify pallets that are impacted by more than one ShipAlt. This first output matrix is shown in Table IV. In the column labeled zone/stage multiple impacts in this matrix, a "1" appears in each cell in which more than one ShipAlt has an impact and a "0" in each cell in which one or no ShipAlt has an impact. Pallets having the potential for time or cost savings are thus clearly identified.

As the ShipAlt designers make more information available, estimates of work content (cost) per pallet, perhaps by estimating parametric material weight and multiplying by the appropriate productivity index, are obtained. This data can then be entered into

## TABLE II: Initial spreadsheet input matrix

| ZONE | STAGE | SAR1 | SAR2 | SAR3 |
|---|---|---|---|---|
| Ml | 1 | | | |
| | 2 | | | |
| M2 | | | | |
| | 1 | | | |
| | 3 | | | |
| M3 | 1 | | | |
| | 2 | | | |
| | 3 | | | |
| M4 | 1 | | | |
| | 2 | | | |
| M5 | 1 | | | |
| | 2 | | | |
| M6 | 1 | | | |
| | 2 | | | |
| Ml | 1 | | | |
| M8 | 1 | | | |
| | 2 | | | |
| M9 | | | | |
| | 1 | | | |
| M10 | 1 | | | |
| | 2 | | | |
| Total = | | | | |

| ZONE | STAGE | SAR1 | SAR 2 | SAR 3 |
|---|---|---|---|---|
| Al | 1 | | | |
| | 2 | | | |
| A2 | 1 | | | |
| | 2 | | | |
| | 3 | | | |
| A3 | 1 | | | |
| | 2 | | | |
| A4 | 3 | | | |
| | 2 | | | |
| A5 | 1 | | | |
| A6 | 1 | | | |
| | 2 | | | |
| Total = | | | | |

| ZONE | STAGE | SAR1 | SAR 2 | SAR3 |
|---|---|---|---|---|
| D1 | 1 | | | |
| | 2 | | | |
| D2 | 1 | | | |
| D3 | 2 | | | |
| D4 | 1 | | | |
| D5 | 1 | | | |
| | 2 | | | |
| Total = | | | | |

| ZONE | STAGE | SAR1 | SAR 2 | SAR3 |
|---|---|---|---|---|
| E/El | 1 | | | |
| | 3 | | | |
| E/E2 | 1 | | | |
| | 2 | | | |
| E/E3 | 3 | | | |
| | 2 | | | |
| E/E4 | | | | |
| | 1 | | | |
| E/E5 | | | | |
| | 1 | | | |
| E/E6 | 1 | | | |
| | 2 | | | |
| | 4 | | | |
| E/E7 | 1 | | | |
| | 2 | | | |
| | 3 | | | |
| Total = | | | | |

## TABLE III: Initial spreadsheet data input

| ZONE | STAGE | SAR1 | SAR2 | SAR 3 |
|---|---|---|---|---|
| | | 1 | 1 | 1 |
| Ml | 1 | 1 | 1 | 1 |
| | | 1 | 0 | 1 |
| M2 | 2 | 0 | 1 | 1 |
| | | 1 | 0 | 1 |
| M3 | 1 | 1 | 1 | 0 |
| | 2 | 1 | 1 | 0 |
| | 3 | 1 | 1 | 0 |
| M4 | 1 | 1 | 0 | 1 |
| | 2 | 1 | 0 | 0 |
| M5 | | 1 | 1 | 1 |
| | 2 | 1 | 1 | 1 |
| M6 | | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 |
| M7 | 1 | 1 | 1 | 1 |
| M8 | 1 | 1 | 1 | 1 |
| | 2 | 1 | 1 | 1 |
| | | 1 | 0 | 1 |
| M9 | 1 | 1 | 1 | 1 |
| | | 1 | 0 | 0 |
| M10 | 1 | 1 | 0 | 0 |
| Total = | | 18 | 12 | 13 |

| ZONE | STAGE | SAR 1 | SAR 2 | SAR 3 |
|---|---|---|---|---|
| Al | 1 | 1 | 0 | 1 |
| | 2 | 1 | 0 | |
| A2 | 1 | 0 | 0 | 1 |
| | 2 | 0 | 0 | |
| | 3 | 0 | 0 | 1 |
| A3 | 1 | 1 | 0 | 1 |
| | 2 | 1 | | |
| | 3 | 0 | 1 | 1 |
| A4 | 1 | 1 | 0 | 1 |
| | 2 | 1 | 0 | 0 |
| A5 | 1 | 1 | 0 | 1 |
| | 2 | 1 | 0 | 1 |
| A6 | 1 | 0 | | |
| | 2 | 0 | 1 | 0 |
| | 3 | 1 | 0 | 1 |
| Total = | | 9 | 0 | 13 |

| ZONE | STAGE | SAR1 | SAR 2 | SAR 3 |
|---|---|---|---|---|
| D1 | 1 | 1 | 0 | 1 |
| | 2 | 1 | 0 | 1 |
| D2 | 1 | 0 | 0 | 1 |
| | 2 | 0 | 0 | 1 |
| D3 | 1 | 1 | 0 | 1 |
| D4 | 1 | 1 | 0 | 1 |
| | 2 | 0 | 0 | 1 |
| D5 | 1 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 |
| Total = | | 4 | 0 | 7 |

| ZONE | STAGE | SAR 1 | SAR 2 | SAR 3 |
|---|---|---|---|---|
| E/E1 | 1 | 1 | | |
| | | 1 | 0 | 0 |
| | 0 | 0 | 0 | 0 |
| E/E2 | | 1 | 1 | |
| | 2 | 0 | 1 | 1 |
| | 3 | 0 | 1 | 0 |
| E/E3 | 1 | 1 | 0 | |
| | 2 | 1 | | 1 |
| E/E4 | 1 | 0 | 1 | |
| | 2 | 0 | 1 | 0 |
| E/E5 | 1 | 1 | 1 | 1 |
| | 2 | 0 | 1 | |
| E/E6 | | 1 | 1 | 0 |
| | 2 | 1 | 1 | |
| | 3 | 1 | 1 | 1 |
| | | 1 | 1 | |
| E/E7 | 1 | 1 | 1 | 1 |
| | 2 | 0 | 1 | 0 |
| | 3 | 1 | 1 | 0 |
| Total = | | 12 | 15 | 9 |

## TABLE IV: Initial spreadsheet output showing multiple impacts

| ZONE | STAGE | SAR1 | SAN 2 | SAR3 | ZONE/STAGE MULTIPLE IMPACTS |
|---|---|---|---|---|---|
| Ml | 1 | 1 | 1 | 1 | 1 |
| | 2 | | 1 | 1 | 1 |
| M2 | 1 | 1 | | 1 | 1 |
| | 2 | 0 | 1 | 1 | 1 |
| | 3 | 1 | 0 | 1 | 1 |
| M3 | 1 | 1 | 1 | 0 | 1 |
| | 2 | | 1 | 0 | 1 |
| | 3 | 1 | 1 | 0 | 1 |
| M4 | 1 | 1 | 0 | 1 | 1 |
| | 2 | 1 | 0 | 0 | 0 |
| M5 | 1 | 1 | 1 | 1 | 1 |
| | 2 | 1 | 1 | 1 | 1 |
| M6 | 1 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 0 |
| M7 | 1 | | 1 | 1 | 1 |
| M8 | 1 | 1 | 1 | 1 | 1 |
| | 2 | 1 | 1 | 1 | 1 |
| M9 | 1 | | 0 | 1 | 1 |
| | 2 | 1 | 1 | 1 | 1 |
| M10 | 1 | 1 | 0 | 0 | 0 |
| | 2 | 1 | 0 | 0 | 0 |
| | Total = | 18 | 12 | 13 | 16 |

| ZONE | STAGE | SAR1 | SAR 2 | SAR 3 | ZONE/STAGE MULTIPLE IMPACTS |
|---|---|---|---|---|---|
| D1 | 1 | 1 | 0 | 1 | 1 |
| | 2 | 1 | 0 | 1 | 1 |
| | | | 0 | 1 | 0 |
| D2 | 1 | 0 | 0 | 1 | 0 |
| D3 | 1 | 1 | 0 | 1 | 1 |
| D4 | 1 | 1 | 0 | 1 | 1 |
| | | 0 | 0 | 1 | 0 |
| D5 | 1 | 0 | | | |
| | 2 | 0 | 0 | [illegible] | 0 |
| | Total = | 4 | 0 | 7 | 4 |

| ZONE | STAGE | SAR1 | SAR 2 | SAR 3 | ZONE/STAGE MULTIPLE IMPACTS |
|---|---|---|---|---|---|
| A l | 1 | 1 | 0 | | |
| | | 1 | 0 | 1 | 1 |
| A2 | 1 | 0 | 0 | 1 | 0 |
| | 2 | 0 | 0 | 1 | |
| | 3 | 0 | | | 0 |
| | | | 0 | 1 | |
| A3 | 1 | 0 | 0 | 1 | 1 |
| | 0 | 0 | 0 | 1 | 0 |
| A4 | 1 | 1 | | | 1 |
| | 2 | 1 | 0 | 1 | |
| A5 | 1 | 1 | 0 | 1 | 0 |
| | 1 | 1 | | | 1 |
| A6 | | | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 0 |
| | 3 | 1 | 0 | 1 | 1 |
| | Total = | 9 | 0 | 13 | 8 |

| ZONE | STAGE | SAN 1 | SAR 2 | SAR 3 | ZONE/STAGE MULTIPLE IMPACTS |
|---|---|---|---|---|---|
| E/El | 1 | 1 | 1 | 0 | 1 |
| | | 1 | 0 | 1 | |
| | 3 | 0 | 0 | 0 | 1 |
| E/E2 | 1 | 1 | 1 | 1 | 1 |
| | 3 | 0 | 1 | 0 | |
| | | | 0 | 0 | 0 |
| E/E3 | 1 | 0 | 0 | 1 | 1 |
| E/E4 | 1 | 0 | 1 | 1 | |
| | | | 1 | 0 | 0 |
| E/E5 | 1 | 1 | 1 | 1 | 1 |
| | | | 1 | 1 | 1 |
| E/E6 | 1 | 1 | 1 | 0 | 1 |
| | 2 | 1 | 1 | 1 | |
| | 3 | 1 | 1 | 0 | 1 |
| | 4 | 1 | 1 | 0 | |
| E/E7 | | | 1 | 1 | 1 |
| | 1 | 1 | 1 | 0 | 0 |
| | 3 | 1 | 1 | 0 | 1 |
| | Total = | 12 | 15 | · 9 | 14 |

## TABLE V: Spreadsheet matrix for entering man-hour estimates

| ZONE | STAGE | ZONE/STAGE MULTIPLE IMPACTS | SAR 1 MANHOUR ESTIMATE | SAR 2 MANHOUR ESTIMATE | SAR 3 MANHOUR ESTIMATE | ESTIMATED MANHOUR SAVINGS |
|---|---|---|---|---|---|---|
| M1 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| M2 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| | 3 | 1 | | | | |
| M3 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| | 3 | 1 | | | | |
| M4 | 1 | 1 | | | | |
| | 2 | 0 | | | | |
| M5 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| M6 | 1 | 0 | | | | |
| | 2 | 0 | | | | |
| M7 | 1 | 1 | | | | |
| M8 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| M9 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| M10 | 1 | 0 | | | | |
| | 2 | 0 | | | | |
| | Total = | 16 | | | | |

| ZONE | STAGE | ZONE/STAGE MULTIPLE IMPACTS | SAR 1 MANHOUR ESTIMATE | SAR 2 MANHOUR ESTIMATE | SAR 3 MANHOUR ESTIMATE | ESTIMATED MANHOUR SAVINGS |
|---|---|---|---|---|---|---|
| D1 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| D2 | 1 | 0 | | | | |
| | 2 | 0 | | | | |
| D3 | 1 | 1 | | | | |
| D4 | 1 | 1 | | | | |
| | 2 | 0 | | | | |
| D5 | 1 | 0 | | | | |
| | 2 | 0 | | | | |
| | Total = | 4 | | | | |

| ZONE | STAGE | ZONE/STAGE MULTIPLE IMPACTS | SAR 1 MANHOUR ESTIMATE | SAR 2 MANHOUR ESTIMATE | SAR 3 MANHOUR ESTIMATE | ESTIMATED MANHOUR SAVINGS |
|---|---|---|---|---|---|---|
| A1 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| A2 | 1 | 0 | | | | |
| | 2 | 0 | | | | |
| | 3 | 0 | | | | |
| A3 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| | 3 | 0 | | | | |
| A4 | 1 | 1 | | | | |
| | 2 | 0 | | | | |
| A5 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| A6 | 1 | 0 | | | | |
| | 2 | 0 | | | | |
| | 3 | 1 | | | | |
| | Total = | 8 | | | | |

| ZONE | STAGE | ZONE/STAGE MULTIPLE IMPACTS | SAR 1 MANHOUR ESTIMATE | SAR 2 MANHOUR ESTIMATE | SAR 3 MANHOUR ESTIMATE | ESTIMATED MANHOUR SAVINGS |
|---|---|---|---|---|---|---|
| E/E1 | 1 | 1 | | | | |
| | 2 | 1 | | | | |
| | 3 | 0 | | | | |
| E/E2 | 1 | 1 | | | | |
| | 2 | | | | | |
| | | 1 | | | | |
| E/E3 | 1 | | | | | |
| | | 0 | | | | |
| E/E4 | 1 | | | | | |
| | 2 | 0 | | | | |
| E/E5 | | | | | | |
| | 2 | 1 | | | | |
| E/E6 | | | | | | |
| | 1 | 1 | | | | |
| | 4 | 1 | | | | |
| E/E7 | 3. | | | | | |
| | | 1 | | | | |
| | 2 | 0 | | | | |
| | Total = | 14 | | | | |
| | OVERALL TOTAL = | 42 | | | | |

appropriate cells in the spreadsheet. Since the ShipAlt designers are alerted to areas of potential synergistic cost savings per pallet, estimates of these savings can be made. This data can then be input into the spreadsheet to permit easy compilation of the total savings associated with zone/stage combination of ShipAlts. Simple manipulation of the spreadsheet permits evaluation of a number of different ShipAlt combinations for potential synergistic savings. Table V shows the spreadsheet into which data is entered as the design process has progressed. Now, man-hour estimates for ShipAlt work by pallet can be input. The estimated savings by combining work from different ShipAlts involving the same pallet can also be input into the appropriate cell in the spreadsheet. Table VI is a final spreadsheet output, indicating all pallets impacted by all ShipAlts being considered, and also providing total cost estimates and synergistic cost savings.

The spreadsheets shown here were programmed using LOTUS l-2-3. The procedure to set up such a spreadsheet matrix (using LOTUS l-2-3 or any other spreadsheet software) is relatively straightforward.

**TABLE VI: Final spreadsheet matrix**

| ZONE | STAGE | ZONE/STAGE MULTIPLE IMPACTS | SAR 1 MANHOUR ESTIMATE | SAR 2 MANHOUR ESTIMATE | SAR 3 MANHOUR ESTIMATE | ESTIMATED MANHOUR SAVINGS |
|---|---|---|---|---|---|---|
| M1 | 1 | 1 | 35 | 53 | 87 | 34 |
| | 2 | 1 | 66 | 46 | 53 | 71 |
| M2 | 1 | 1 | 35 | 0 | 64 | 28 |
| | 2 | 1 | 0 | 25 | 34 | 0 |
| | 3 | 1 | 68 | 0 | 35 | 35 |
| M3 | 1 | 1 | 76 | 78 | 0 | 33 |
| | 2 | 1 | 68 | 35 | 0 | 12 |
| | 3 | 1 | 46 | 84 | 0 | 42 |
| M4 | 1 | 1 | 86 | 0 | 97 | 75 |
| | 2 | 0 | 56 | 0 | 0 | 0 |
| M5 | 1 | 1 | 46 | 23 | 53 | 32 |
| | 2 | 1 | 46 | 26 | 68 | 57 |
| M6 | 1 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 0 | 0 |
| M7 | 1 | 1 | 57 | 37 | 86 | 57 |
| M8 | 1 | 1 | 86 | 26 | 54 | 46 |
| | 2 | 1 | 25 | 74 | 54 | 12 |
| M9 | 1 | 1 | 25 | 0 | 87 | 0 |
| | 2 | 1 | 75 | 54 | 76 | 46 |
| M10 | 1 | 0 | 75 | 0 | 0 | 0 |
| | 2 | 0 | 68 | 0 | 0 | 0 |
| | Total = | 16 | 1039 | 561 | 848 | 580 |

| ZONE | STAGE | ZONE/STAGE MULTIPLE IMPACTS | SAR 1 MANHOUR ESTIMATE | SAR 2 MANHOUR ESTIMATE | SAR 3 MANHOUR ESTIMATE | ESTIMATED MANHOUR SAVINGS |
|---|---|---|---|---|---|---|
| D1 | 1 | 1 | 46 | 0 | 45 | 37 |
| | 2 | 1 | 46 | 0 | 68 | 26 |
| D2 | 1 | 0 | 0 | 0 | 86 | 0 |
| | 2 | 0 | 0 | 0 | 34 | 0 |
| D3 | 1 | 1 | 57 | 0 | 86 | 38 |
| D4 | 1 | 1 | 86 | 0 | 54 | 46 |
| | 2 | 0 | 0 | 0 | 54 | 0 |
| D5 | 1 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 0 | 0 | 0 | 0 |
| | Total = | 4 | 235 | 0 | 427 | 147 |

| ZONE | STAGE | ZONE/STAGE MULTIPLE IMPACTS | SAR 1 MANHOUR ESTIMATE | SAR 2 MANHOUR ESTIMATE | SAR 3 MANHOUR ESTIMATE | ESTIMATED MANHOUR SAVINGS |
|---|---|---|---|---|---|---|
| A1 | 1 | 1 | 46 | 0 | 63 | 33 |
| | 2 | 1 | 78 | 0 | 56 | 50 |
| A2 | 1 | 0 | 0 | 0 | 64 | 0 |
| | 2 | 0 | 0 | 0 | 65 | 0 |
| | 3 | 0 | 0 | 0 | 26 | 0 |
| A3 | 1 | 1 | 37 | 0 | 32 | 17 |
| | 2 | 1 | 54 | 0 | 34 | 25 |
| | 3 | 0 | 0 | 0 | 86 | 0 |
| A4 | 1 | 1 | 31 | 0 | 65 | 22 |
| | 2 | 0 | 56 | 0 | 0 | 0 |
| A5 | 1 | 1 | 46 | 0 | 45 | 0 |
| | 2 | 1 | 46 | 0 | 68 | 41 |
| A6 | 1 | 0 | 0 | 0 | 86 | 0 |
| | 2 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 1 | 46 | 0 | 68 | 33 |
| | Total = | 8 | 440 | 0 | 758 | 221 |

| ZONE | STAGE | ZONE/STAGE MULTIPLE IMPACTS | SAR 1 MANHOUR ESTIMATE | SAR 2 MANHOUR ESTIMATE | SAR 3 MANHOUR ESTIMATE | ESTIMATED MANHOUR SAVINGS |
|---|---|---|---|---|---|---|
| E/E1 | 1 | 1 | 4 | 45 | 0 | 4 |
| | 2 | 1 | 46 | 0 | 68 | 39 |
| | 3 | 0 | 0 | 0 | 0 | 0 |
| E/E2 | 1 | 1 | 75 | 75 | 86 | 43 |
| | 2 | 1 | 0 | 35 | 86 | 13 |
| | 3 | 0 | 0 | 76 | 0 | 0 |
| E/E3 | 1 | 0 | 46 | 0 | 0 | 0 |
| | 2 | 1 | 36 | 0 | 68 | 31 |
| E/E4 | 1 | 1 | 0 | 34 | 86 | 18 |
| | 2 | 0 | 0 | 32 | 0 | 0 |
| E/E5 | 1 | 1 | 86 | 34 | 54 | 46 |
| | 2 | 1 | 0 | 43 | 54 | 0 |
| E/E6 | 1 | 1 | 43 | 53 | 0 | 15 |
| | 2 | 1 | 75 | 36 | 76 | 46 |
| | 3 | 1 | 75 | 54 | 0 | 41 |
| | 4 | 1 | 75 | 34 | 0 | 24 |
| E/E7 | 1 | 1 | 68 | 35 | 57 | 53 |
| | 2 | 0 | 0 | 87 | 0 | 0 |
| | 3 | 1 | 75 | 87 | 0 | 50 |
| | Total = | 14 | 704 | 760 | 635 | 423 |
| OVERALL TOTALS = | | 42 | 2418 | 1321 | 2668 | 1371 |

## RECOMMENDATIONS

### 1. IMPROVE THE MANUFACTURING SYSTEM

There is great need for OpNav and NavSea to recognize that a shipyard's ability to improve itself while implementing ShipAlt work is just as much a military requirement as upgrading weapons systems in warships. Fortunatelv. virtuallY all militarv and technical improvements can be achieved while simultaneously and manifestly providing for manufacturing system improvement.

OpNav should state, "A shipyard's ability to improve its manufacturing system during implementation of any work is a military requirement."

NavSea should state in The Fleet Modernization Program Management and Operations Manual, "Shipyards shall provide for improvements in their manufacturing systems during ShipAlt implementation."

Significant improvement is dependent upon concerted application of all of the basic management functions, that is:

- estimating,
- planning (design is an aspect of planning),
- scheduling,
- implementing (both material marshalling and producing), and
- evaluating.

Therefore, with particular emphasis on those who participate in developing contract requirements, a manufacturing system must be regarded as including all organizations that influence how shipyards perform. For ShipAlt work they include:

- Ship Logistics Managers (SLMs) /Program Managers (PMs),
- Type Commanders (TyComs),
- Engineering Directorates (EDs), and
- planning yards.

SLMs, PMs, TyComs, and EDs are customers. They should understand that their best interests are served when their military and technical requirements are formatted in a way that permits further refinement and eventual implementation per modern, zone oriented manufacturing technology.

Planning yards serve two masters. They function as agents of customers during their preparation of:

- ShipAlt Records, that is, preliminary design activities that are sufficient for ShipAlt programming decisions, and
- SIDs that have the effect of contract drawings.

And they serve implementing shipyards during their preparation of such other SIDs that are required.

OpNav should state, "Because contract design is part of the manufacturing system, SLMs/PMs, Tycoms, and EDs, shall negotiate, preferably with implementing yards, but otherwise with planning yards acting as surrogates, for the purpose of incorporating effective implementation strategies in contract drawings."

### 2. DEVELOP GENERIC STRATEGIES PER SHIP CLASS

Zone/stage control of work combined with addressing each type of work separately (for example, light-fitting rip out and heavy-fitting rip out), are all that are needed to devise a very useful, generic alteration strategy by ship class. That part of a strategy that applies to a single specialty within one ship class, say for machinery spaces, since it is by type of work, will be similar to that required for another ship class. Thus, very much can be adapted from class to class by just taking into account the different compartmentation.

OpNav should authorize a special project for the purpose of developing generic strategies that planning yards should use to preview how zone oriented work is most likely to be implemented.

NavSea should direct planning yards to provide codes in their design models so that they can offer implementing yards a choice of information in zone/stage groups that match a generic strategy or in traditional system-by-system groups.

### 3. INSTITUTE ZONE ORIENTED DESIGN STAGES

Contract and functional design are distinct stages in a traditional design approach. Transition and work instruction design stages do not exist. Zone orientation features system-by-system expertise applied to functional matters and initial material definition, but it also relies on zone oriented expertise per regional specialty, particularly for detail design and exact material definition. As more than two thirds of design man-hours are spent on detail design, the corporate culture will change for the majority involved in ShipAlt design efforts.

The change will entail a culture shock for many who believe they have achieved security by commanding design aspects of a particular function. Their vision cannot be expected to include optimizing implementation of entire ShipAlts nor their roles as de facto participants in a manufacturing system which has the obligation to continually improve.

NavSea should provide special assistance to planning yards in the form of programs to indoctrinate designers in zone logic, to identify people who cannot make the transformation, and to provide such people with other work or early retirement.

NavSea should require planning yards to implement the four distinct zone logic design stages, including, contract, functional, transition, and work instruction.

## 4. ESTABLISH PRODUCTION ENGINEERING IN PLANNING YARDS

Although a generic strategy per a ship type would be available, each planning yard would still require its own production engineers. They would be required at first to adjust a generic strategy in the context of a particular set of ShipAlts authorized for simultaneous implementation. Until an implementing yard is designated, planning yard production engineers would have to refine their strategy as design progress makes more information available.

NavSea should require each planning yard to develop a production engineering capability for each specialty represented in the ship classes assigned to them. Each person so assigned should have keen understanding of ship operational, ship maintenance, and shipyard manufacturing system matters for the specialty assigned.

## 5. SHIFT TO PRODUCT ORIENTED MATERIAL MANAGEMENT

Since material is the only tangible, the most effective shipyard management systems control production through control of material. Consumed man-hours are reported per physical characteristic of the interim products completed and according to the problems they impose, for example, man-hours: per length of electric-cable pulled separately for large, medium and small diameters; per pipe pieces fabricated separately by pipe-piece family; and per weight of electronic work packages separately for shop assembly and for on board assembly.

Statistical analyses of man-hour cost returns identify how such work normally (mean values and standard deviations) performs and are the bases for man-hour budgeting and scheduling. When constant comparisons by computer disclose material types or volumes defined during any design stage that exceed those in the contract design material budget, budgeted man-hours increase accordingly and schedules have to be confirmed or adjusted. In order to maintain the validity of the material/man-hour corporate data, certain material management techniques are required.

Since they influence material/man-hour relationships, certain U.S. Navy purchasing activities, and material suppliers including those for Centrally Provided Material (CFM) are also de facto parts of a yard's manufacturing system. In other words both material and production responsibilities are operational matters that should respond to the same ship modernization strategy. Further, the productivity of a manufacturing system is dependent upon knowing beforehand how material suppliers will perform as well as how their products will perform. Therefore operational considerations should be the primary basis for procurement regulations that shipyards must follow.

OpNav should, except for CPM and LLTM necessarily ordered before an implementing yard is designated, transfer all remaining material procurement responsibilities to implementing yards. This recommendation is peculiar to naval shipyards because they are required to employ purchasing activities outside of their commands for a significant part of their material procurement activities.

NavSea should work to remove any restrictions that may exist that prevent shipyards from initially ordering certain materials from diagrammatics, and from limiting the number of eligible bidders for productivity reasons. Large amounts of corporate data are essential for a modern manufacturing system. Regarding each product, this includes design details, approval status, quality, accuracy, ILS, prices, scheduled delivery record, and guarantee service record. Attempting to build the needed file of corporate data without limiting the number of prospective bidders for each item to no more than three, is simply impractical.

NavSea should require naval shipyards, and should recommend to private shipyards, that they employ the allocated stock (AS) material management concept.

NavSea should require naval shipyards, and should recommend to private shipyards, that they relate materials to man-hours.

NavSea should require naval shipyards, and should recommend to private shipyards, that they employ a computer to constantly compare materials being defined in later design stages to material budgets developed during contract design.

## 6. GENERAL

NavSea, as well as all those involved in the construction, modernization, overhaul and repair of naval ships, have a critical need to reexamine the way in which information, people, material and work are organized. Although the benefits of exploiting zone technology in production work are generally recognized, the rest of the manufacturing system has not been evaluated and altered to suit this approach. In general, most participants in the manufacturing system continue to employ system-by-system thinking for all preparations leading to production. Just before production starts, attempts are then made to reorganize information to utilize zone technology in production. One strategy is employed until production work is to start, and then a switch to a completely different one is made. This situation is the result of a manufacturing system that has evolved over many years.

This paper sets forth the premise that all parts of the ship modernization, overhaul and repair process should be recognized as being part of one manufacturing system. Thus the activities of planning yards are a critical part. Further, specific guidance for how planning yards should go about preparing ShipAlt information in order to facilitate implementation of zone logic is provided. OpNav and NavSea should review, evaluate and act upon these recommendations as a means of improving it's ability to manage the construction, modernization, overhaul and repair of the naval fleet. As a practical matter, Navsea should revise and update the FMP Manual to reflect the goal of supporting and encouraging the productivity gains that can be achieved by employing zone logic in ship repair, overhaul and modernization programs. Suggestions for many of the revisions are provided in Part 3 of the report to Panel SP-4, upon which this paper is based.

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